SYSTEMS AND METHODS FOR IMAGING AND MANIPULATING TISSUE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a divisional of U.S. application Ser. No. 14/852,460, filed Sep. 11, 2015, which claims priority to U.S. Provisional Patent Application Ser. No. 62/049,955 filed Sep. 12, 2014, the contents of each of which are incorporated by reference herein.

BACKGROUND INFORMATION

[0002] Traditional surgical techniques and apparatus have utilized independent systems and components for imaging and manipulating tissue. For example, a first system may be used to image the area in which the surgical technique is to be performed, while separate systems may be used to coagulate and cut the tissue.

[0003] The use of multiple independent systems can reduce the accuracy of the procedure, as the surgeon is not able to manipulate the tissue in spatial and/or temporal registration with preferred tissue visualization. In addition, the use of separate systems for independent functions performed during surgical procedures can result in increased surgical times as each system must be introduced and withdrawn from the surgical site, increasing patient morbidity and mortality. Other issues arising from the use of multiple surgical systems include limited access to surgical sites for multiple systems and increased costs.

[0004] Traditional systems and techniques may also use mechanical components for tissue manipulation that can lead to trauma to surrounding tissues and longer recovery times for patients. In addition, the inability to concurrently image and cut has resulted in the inability to perform certain operations, or to perform operations inadequately requiring repeat procedures in the future.

[0005] Many neurologic cancer surgeries require specialized tools that enhance imaging for precise cutting and removal of tumor cells and tissues without damage to adjacent benign structures. For example, brain tumors are accessible via the ventricles but inoperable because the surgeon cannot concurrently image the boundary between tumor and healthy tissue and establish a safe margin. Although prestaging imaging and surgical operating procedures have improved considerably over the last two decades, rate of successful outcomes (i.e., cancer-free patients) have not meaningfully improved. A leading hypothesis for the existing high recurrence rate and corresponding poor outcomes is that cancer cells are being left within the patient due to improper selection of tumor margins. Current methods utilized for tumor margin selection using traditional biopsy during surgery are limited and time-consuming. Current practice requires the surgeon to physically label tissue regions for biopsy, perform the biopsy, manually transfer tissue to a pathology laboratory, creation of frozen sections and sectioning, staining the frozen section, diagnostic observation of frozen tissue sections under a microscope by a cancer pathologist and finally oral communication of the diagnostic results back to the surgeon—a process that requires about thirty minutes and is disruptive to the surgeon's preferred workflow.

[0006] Accordingly, systems and methods are desired that overcome these and other limitations associated with existing systems and methods.

SUMMARY

[0007] Exemplary embodiments of the present disclosure include systems and methods capable of imaging and manipulating tissue using light, including for example, coagulating and breaking the molecular bonds (e.g. cutting) tissue. Particular embodiments may be configured for use in neurosurgery, ear, nose and throat (ENT) procedures, obstetrics, gynecology, gastroenterology, lung procedures, peripheral nerve surgery, or other applications.

[0008] Exemplary embodiments utilize advantages of light energy to image and manipulate tissue, including simultaneously imaging and manipulation in some embodiments. For example, light has the capacity to transmit large amounts of encoded information (e.g. 300 THz) at subcellular spatial scales (1 μm). In addition, light can penetrate epithelial tissue layers without an incision, since light can modify a desired target by photon absorption or photon momentum transfer (scattering). Particular embodiments utilize optical coherence tomography (OCT) and/or multiphoton luminescence (MPL) systems and components to image the tissue, and lasers to provide light for manipulating tissue, including coagulating and breaking the molecular bonds of tissue.

[0009] Exemplary embodiments of the present disclosure integrate three novel laser technologies for imaging, coagulation (e.g. blood flow interruption) and tissue removal (e.g. tissue "cutting") and inspire a new surgical paradigm. Capability for image-guided high speed tissue removal with a cutting precision of a few cell layers is unprecedented in the surgical arts. Exemplary embodiments will allow access to remove previously inoperable tumors and other pathologic tissues in small confined spaces. Accordingly, surrounding nerves, specialized muscles and important glands can be spared, thereby substantially improving a patient's prognosis following surgery.

[0010] Exemplary embodiments may be utilized for surgical removal of many complex lesions in close proximity with specialized nerves, muscles, glands, and other normal organs and supporting structures. For example, endometriosis is frequently associated with the ovary, bowel and bladder, and other abdominal structures, and removal using conventional surgical procedures poses a risk of diminishing the longevity of fertility to the female patient due to a loss of ovum or eggs, or contamination of the abdomen with feces or urine. Exemplary embodiments may rapidly safely, and more precisely remove ovarian lesions sparing normal ovarian follicles, and remove endometrial tissue without the risk of bacterial contamination of the sterile abdominal cavity.

[0011] Certain embodiments include a system comprising: a first light source configured to provide a signal for use in imaging tissue when the first light source is incident upon tissue; a second light source configured to coagulate tissue (e.g. surrounding blood vessels); and a third light source configured to break molecular bonds of tissue coagulated by the second light source when the third light source is incident upon tissue. In particular embodiments, the first light source, the second light source and the third light source emit light through a single fiber (or larger structures such as an endoscope or laproscope) at the same instance. In